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Increasing Reservoir Storage or Spillway Capacity using Fusegates

by John Hite, Jr., and Charles Mifkovic

PURPOSE: The purpose of this Technical Note is to provide basic information on the operation of fusegates and their use for flood control projects. A brief description of a site specific fusegate model study performed for the U.S. Army Engineer District, Sacramento is also included.

INTRODUCTION: Fusegates were invented in 1989 as a simple and safe system to increase reservoir storage or spillway capacity. The system has been patented by Hydroplus International in the United States, Europe, and other countries. Hydroplus has installed fusegates on over 30 dams worldwide, including an irrigation dam in New Mexico.

The fusegate is a nonmechanical structure consisting of three main components; a bucket, a base, and an intake well connected to a chamber in the base (Figure 1). For a retrofit on an existing spillway, a portion of the ogee crest is removed and provided with a flat surface. If only an increase in spillway capacity is needed, the crest of the fusegates is set near the crest elevation of the original ogee. To increase storage, the crest of the fusegates is set higher than the original ogee crest elevation. The fusegates are set side by side on the flat surface across the width of the original spillway. For new construction, a flat surface is provided initially.

BASIC OPERATION: At most installations, the fusegate functions like an aerated labyrinth weir for discharges up to the design discharge. For discharges greater than the design flow, flow enters the intake wells and into the chamber at the base of the gate. The intake well (shown in Figure 1) is located directly above the base of the fusegate. The intake well can be located remotely and connected to the base of the gate using conduits. Accumulation of seepage water in the bottom chamber is prevented by providing each chamber with two drains. The vertical joint between adjacent fusegates is sealed (usually with a flat rubber gasket), and these seals are only attached to one of the two adjacent gates.

As flow from the intake well exceeds the flow out of the drain holes in the bottom chamber, the water level in the well increases. This results in increased pressure in the bottom chamber that exerts an uplift force on the gate. The uplift force causes the gate to become unstable and at a predetermined depth of water in the well, the fusegate tilts by rotating about its downstream edge. The crest of the intake well in each fusegate is set at a different elevation so that the fusegate tips at a predetermined discharge and water-surface elevation in the reservoir. The well crest elevations for adjacent gates are set to avoid adjacent gates tipping simultaneously. This always allows the fusegates to tilt away from the gate to which the side seals are attached. Falvey and Treille (1995) investigated the fusegate hydraulics and design and provided much information concerning design procedures and discharge characteristics.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **APR 2000**	2. REPORT TYPE	3. DATES COVERED **00-00-2000 to 00-00-2000**
4. TITLE AND SUBTITLE **Increasing Reservoir Storage or Spillway Capacity using Fusegates**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Army Engineer Research and Development Center,Coastal and Hydraulics Laboratory,3909 Halls Ferry Road,Vicksburg,MS,39180**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

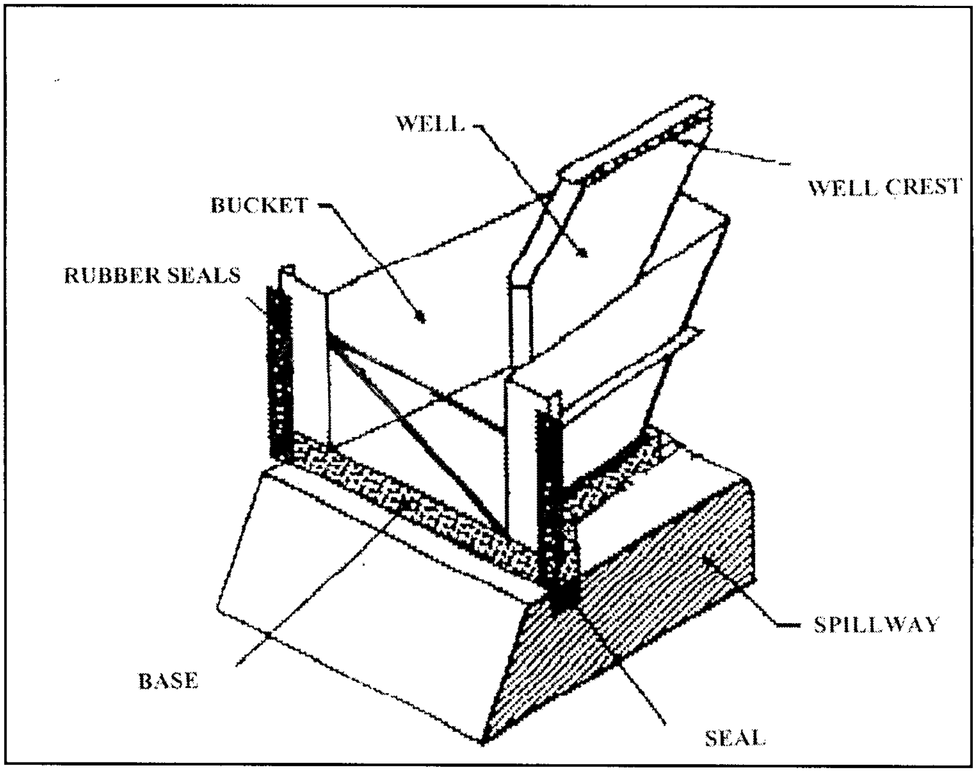

Figure 1. Schematic of fusegate

LAKE KAWEAH FUSEGATE DESIGN: The Sacramento District is considering a fusegate design for Lake Kaweah spillway near Visalia, CA. Increased flood protection and water supply benefits can be achieved by increasing the reservoir storage from 52,546,326 cu m (42,600 acre-feet (AF)) to a reservoir capacity of 228,194,133 cu m (185,000 AF).

A total of six fusegates are required for the Lake Kaweah spillway, each 11.70-m- (38.4-ft-) wide, 6.50-m- (21.33-ft-) high, and 12.98-m (42.6-ft) in length at the crest. The fusegates will fit in a 70.22-m (230.4-ft) rectangular opening within the existing spillway. Concrete overflow sections will fill the gap between the fusegates and sidewalls of the existing spillway. The Lake Kaweah spillway has a trapezoidal-shaped approach channel 76.20-m- (250-ft-) long with a notched section that has a 41.15-m (135-ft) bottom width and side slopes of 1V on 0.5H. The top sides of the notched section are referred to as benches and will require some excavation. The spillway exit channel is shaped the same as the approach channel, and is 289.55-m- (950-ft-) long on a slope 0.01.

PHYSICAL MODEL STUDY: A physical model study of the fusegates was considered necessary to evaluate the performance of the fusegate spillway design for flows up to the Probable Maximum Flood (PMF) and insure the design functions as intended. The Lake Kaweah site contained design features that had not been previously verified for fusegates. These included submergence effects during operation and highly fluctuating water levels in the approach channel. There was also concern over the tumbling action of the fusegates due to the

mild slope in the exit channel. If the gates did not wash downstream after tipping, they could still act as a flow control and the pool elevation would not be as low as desired.

Flow over the fusegates will not occur until the flood frequency exceeds an 80-year event, 1048 cu m/sec, (37,000 cfs). The fusegates were designed to tip in a range of pool elevations from 1.2H to 1.4H above the crest of the fusegates, where H is the height of the fusegate from invert to crest. In terms of flood frequency, the first fusegate will not tip until the pool elevation is at the maximum expected pool elevation for the 1,000-year frequency flood. The fusegates then begin a controlled tipping sequence for flows between 4,587 and 7,504 cu m/sec (162,000 and 265,000 cfs). Once the flow reaches 7,504 cu m/sec (265,000 cfs), the fusegates are displaced and no longer affect the upstream reservoir level. During the PMF after all the fusegates have tipped, the maximum pool elevation will be slightly less than the objective design pool elevation. This will provide 1.0 m (3.3 ft) of freeboard below the elevation of the top of the dam.

The 1:30-scale model reproduced a portion of the upstream reservoir, the fusegate spillway (six gates), the fusegate intake wells, and the exit channel. The model study was conducted at Utah State University. The model was designed for prototype outflows up to 8,495 cu m/sec (300,000 cfs). Figure 2 shows the model without flow and the six fusegates placed on top of the sill. Figure 3 shows the intake wells for three of the fusegates. The wells were initially located at each abutment of the spillway and were connected individually to the fusegate using conduits. Because the high velocity flow in the approach channel caused fluctuations in the water levels of the intake well towers affecting fusegate performance, all of the intake wells were relocated to the right abutment, and a conduit extending into the reservoir was used to transport water into the intake tower.

The initial model gates were fabricated from an epoxy resin material and were not allowed to repeatedly tilt and roll down the exit channel. In subsequent model tests, aluminum gates were used to evaluate the tumbling action of the gates in the exit channel. The model fusegates were scaled using Froude criteria. The weight and center of gravity of the model fusegates were reproduced accordingly.

Flow over the model spillway is shown in Figure 4 for a discharge less than the 80-year frequency flood. Figure 5 shows the flow over the fusegate after the first gate has tipped and washed downstream. Flow over the spillway with the PMF discharge is shown in Figure 6.

SUMMARY OF MODEL INVESTIGATION: The results from the model study of the Lake Kaweah spillway fusegates indicated the fusegates could provide the increased flood protection required at the project. The hydrodynamics of the approach channel and exit channel were not significantly affecting the tipping of the fusegates. The high velocity in the approach caused a fluctuating water level in the intake well. Modifications were made to the intake wells to insure the gates tipped at the desired pool elevations and discharges. After tipping, the fusegates tumbled downstream and did not cause any backwater effects.

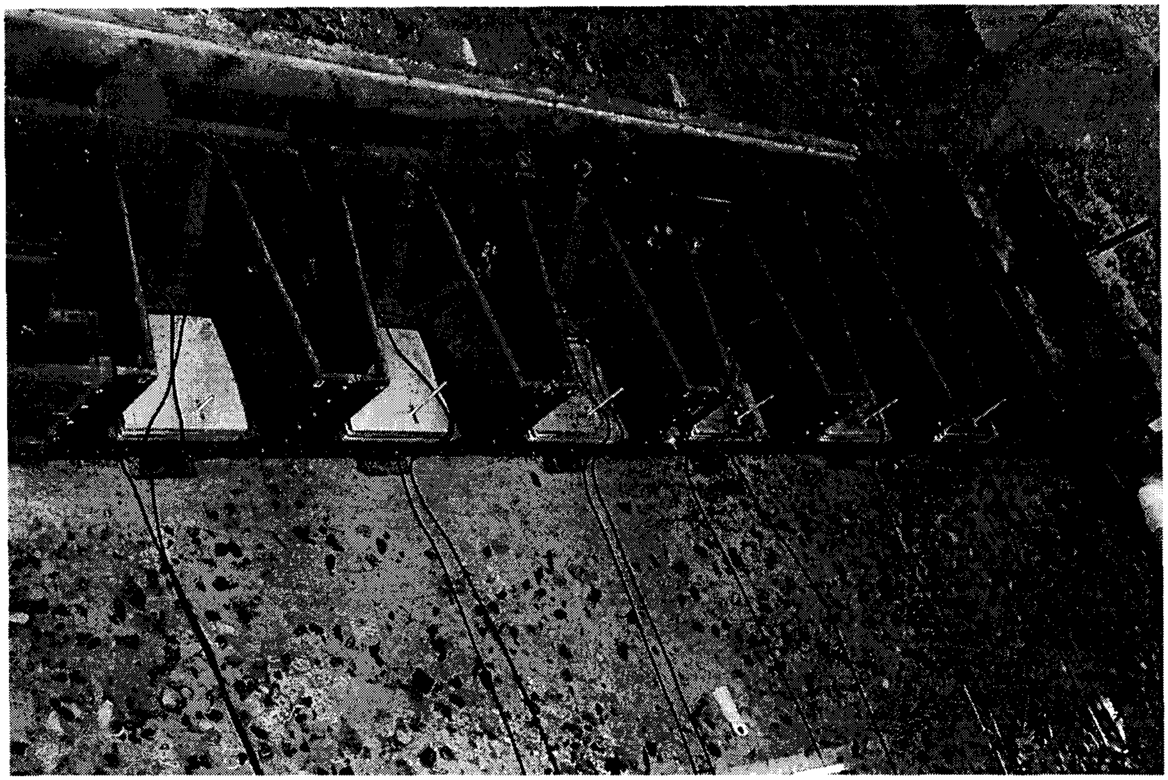

Figure 2. Dry bed view of Lake Kaweah model fusegates (flow is from bottom to top)

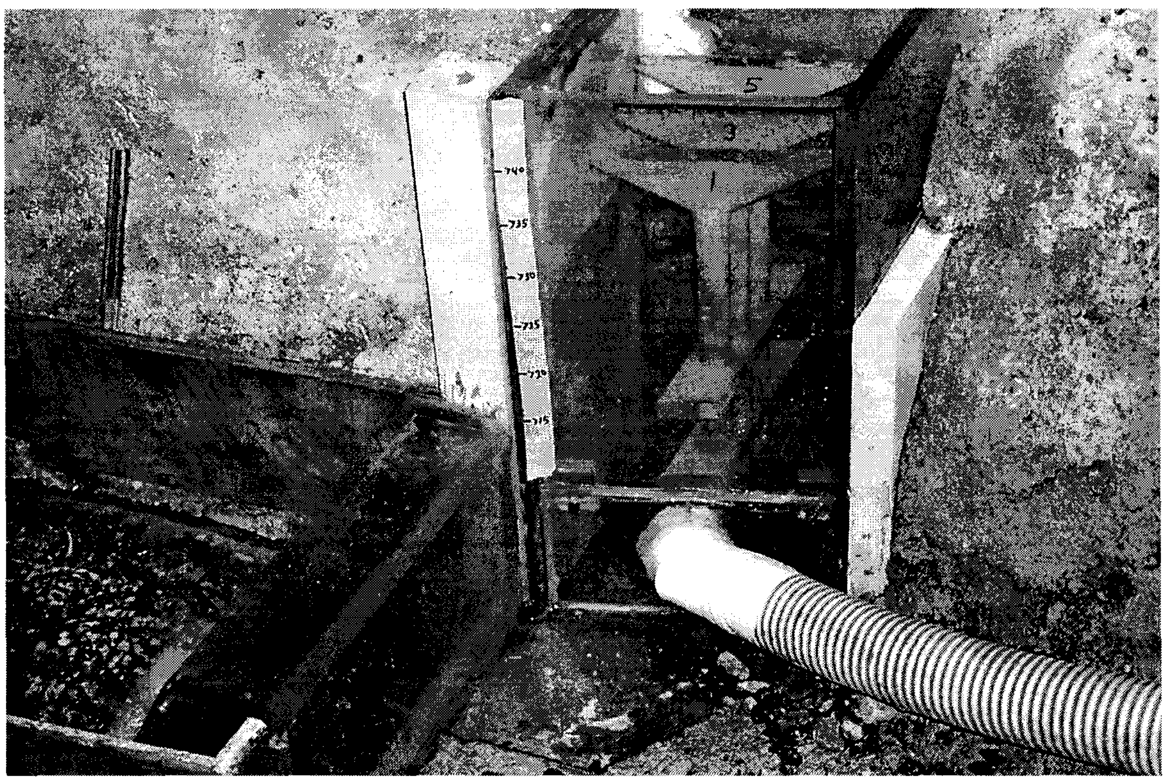

Figure 3. Intake wells for three fusegates (located on the right spillway abutment)

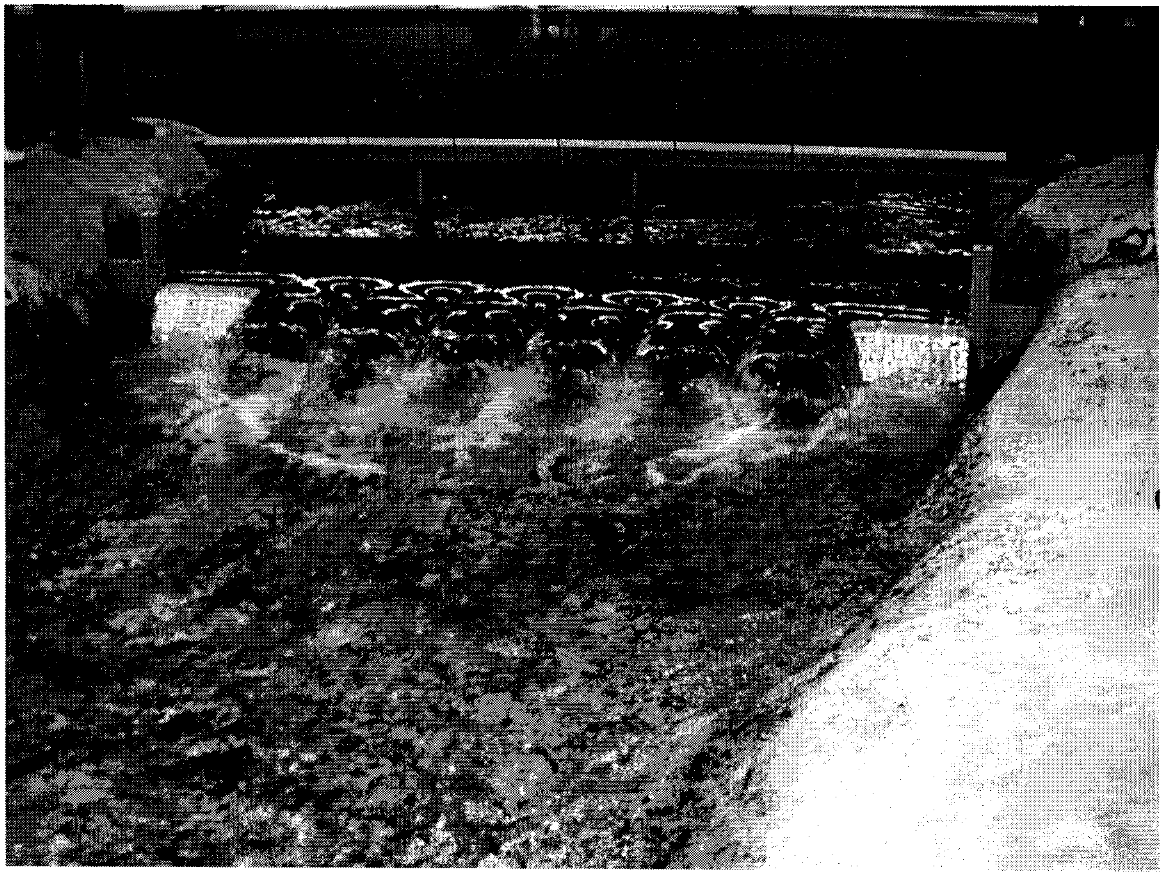

Figure 4. Looking upstream at flow over the fusegates with a discharge less than 37,000 cfs

Figure 5. Looking upstream at flow over the fusegates after two of the gates have tipped and washed downstream

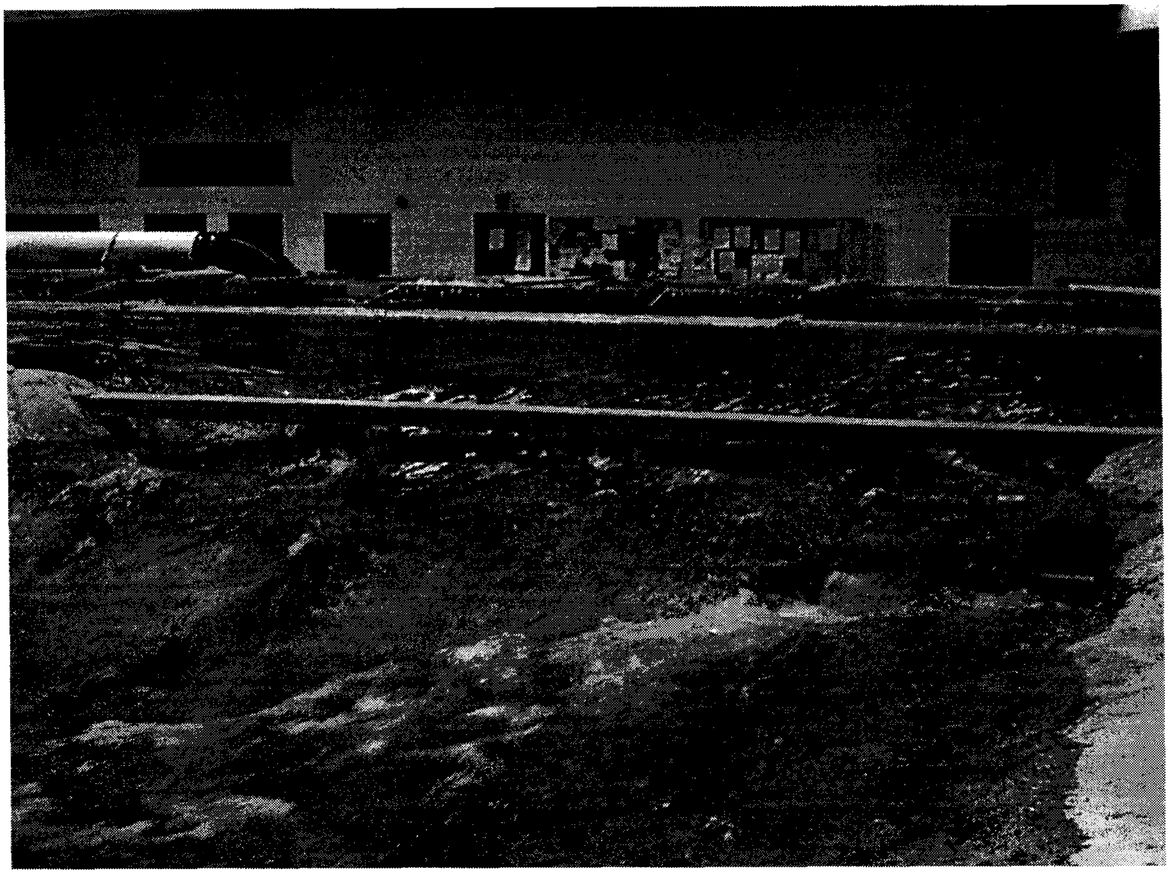

Figure 6. Looking upstream at flow conditions through the spillway with the PMF discharge

ADDITIONAL INFORMATION: For additional information contact Dr. John E. Hite, Jr., USAE ERDC, Coastal and Hydraulics Laboratory, Navigation Branch, at 601-634-2402 or e-mail *hitej@wes.army.mil;* or Charles Mifkovic, USAE District Sacramento, Engineering Division, at 916-557-7254 or e-mail *Cmifkovic@spk.usace.army.mil.*

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Falvey, H. T. and Treille, P. (1995). "Hydraulics and design of fusegates," *Journal of Hydraulic Engineering,* ASCE, 121(7), 512-518.